A Planning Tool For Assessing Stormwater Management Storage Requirements

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Introduction

With stormwater management criteria now in force or coming into existence throughout the state, planners need a tool to assess the impact of a proposed land use change on the hydrology of the basin within which the development will take place. In general, such development usually has two major impacts on basin hydrology. First, it increases the imperviousness of the basin and thus increases the volume of runoff from a given storm. Second, it increases the velocity of flow in the basin thus decreasing the time it takes water to travel from an upstream point to a reference point downstream. These two phenomena combine in most cases to drastically increase both total volumes of runoff and peak rates of flow in a basin that has undergone development.

The prevailing philosophy in those rapidly urbanizing counties in Maryland where a stormwater management policy exists is to require that any future development scheme include a plan which will reduce post development peak discharges for a certain key storm to a level at or below that which existed prior to development for a similar storm. In order to accomplish this, engineers and developers must find ways to either store or retain excess runoff or increase travel times in order to reduce peake rates of flow to pre-development levels.

In general, the former scheme is far more practical as a method of peak reduction. The procedure for determining volumes of storage required is, briefly, as follows: Using approved engineering procedures (the USDA Soil Conservation Service procedures are widely accepted), the engineer computes the volume of runoff and peak rate of flow for the key storm under existing land use conditions. In most cases the key storm is one with a 24 hour duration and a 2 or 10 year frequency. This is the case because most literature on the subject indicates that it is this range of storm events that "landscapes" stream banks and stream beds. The peak rate of discharge then becomes the index criteria for stormwater management design: any SWM system must reduce future discharge for the key storm down to this pre-development level. The developer then computes volume of runoff and peak rate of discharge with assumed future land use conditions. He then goes about designing a system (surface ponds, parking lot or rooftop storage, underground tanks, etc.) that affects reduction

of post development peak discharge to pre-development peak discharge.

The procedure is fairly straight-forward and for individual sites the hydrologic computations can usually be done in a few hours. However, the planner who may be working with several hundred acres and evaluating several proposals for solving SWM problems is faced with an entirely different problem. Compiling the necessary input data to do the same detailed evaluation as on an individual site would be an arduous, time-consuming task. Furthermore, it would imply accuracy beyond the scope of the analysis. Therefore, the planner needs a tool which 1) will allow him to assess the impact on various development alternatives on basin hydrology and therefore stormwater management needs; 2) is straight-forward and will allow for rapid analysis; and 3) is accurate within the level of intensity of his evaluation.

It is to this end that this procedure has been developed.

Basis for the Procedure

The major basis for this approximation tool is the assumption that for general area planning (areas of 100 to 2000 acres in size) stormwater management storage requirements can be approximated using increased volumes of runoff only and that rates of flow can be ignored. Remember, this assumption will be considered valid for area planning only. It would be foolhardy to carry it over into specific site design.

The effect of changed land use on basin hydrology is demonstrated in the comparison of pre and post development runoff hydrographs as seen in Figure 1.

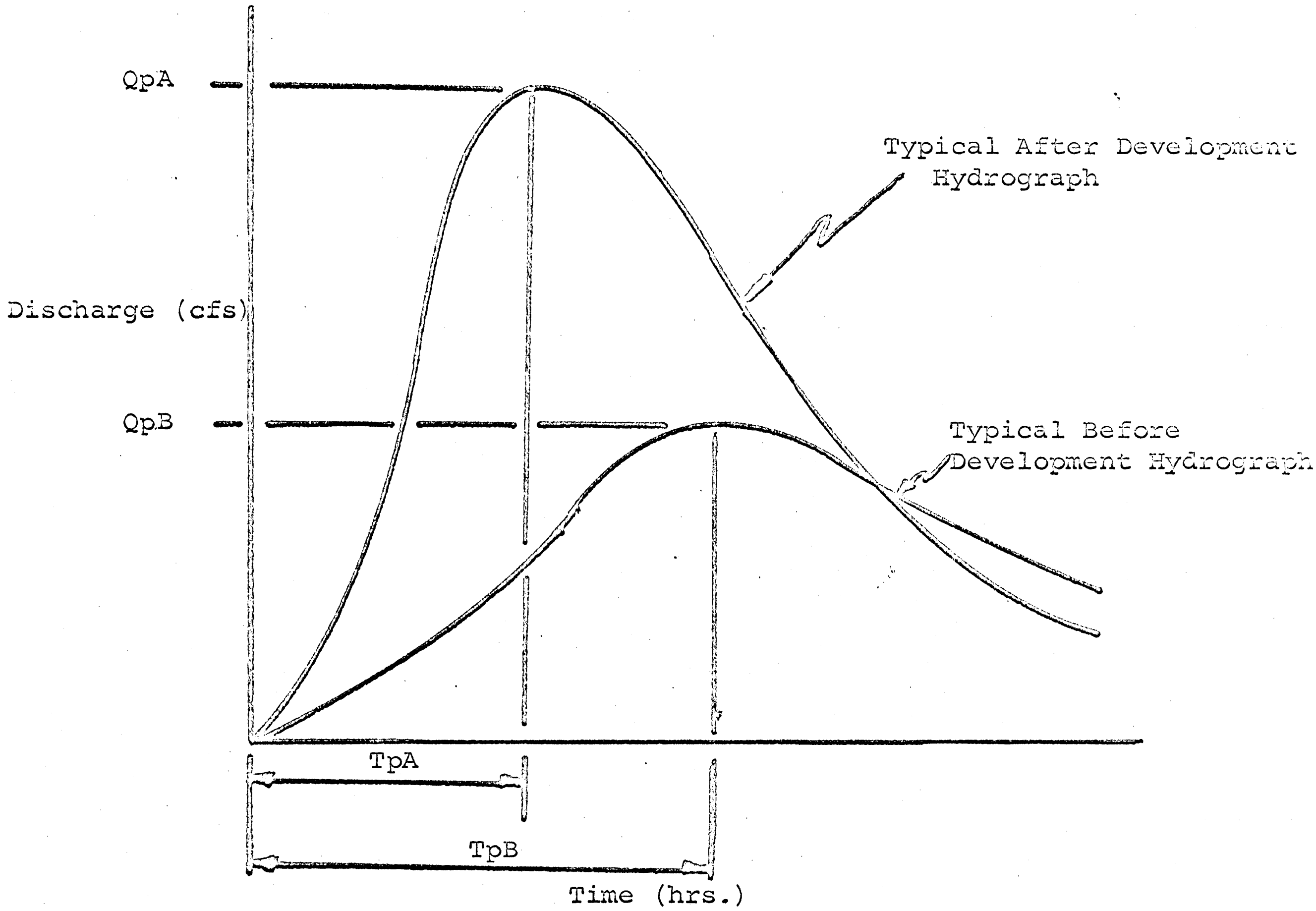

Figure 1

Impact of Urbanization
or
Typical Subarea Runoff Hydrograph

One can note 3 phenomena from Figure 1:

1) The peak discharge increased from pre to post development conditions;

2) The time to peak discharge decreases from pre to post development conditions; and

3) The total volume of runoff, as depicted by the area under the curves, increases from pre to post development conditions.

The goal of stormwater management is to reduce Q_pA down to Q_pA. We will examine a means of accomplishing this, using the continuity equation, which states simply that for a given period of time, Inflow (I) minus Outflow (O) is equal to the change in storage.

$$\text{or } I - O = \Delta S$$

In stormwater management analysis, if one assumes that the inflow is represented by the post development hydrograph and the outflow up to the time of peak outflow is approximated by the pre-development hydrograph , it can be seen that the volume of storm water that must be stored is represented by the shaded area in Figure 1a.

It can also be seen that the amount of storage required would be represented by the difference between the area under the after-development hydrograph and the area under the before-development hydrograph up to time TpB. If we then can establish a relationship between this volume and the difference in total volume between the pre and post development hydrographs, it will allow us to express Volume of Storage required for stormwater management (V_s) as a function of the difference between pre and post development runoff volume.

If the pre and post development hydrographs have the configuration shown in Figure 2a, the volume of storage, shown shaded, would be greater than the difference in total runoff between pre and post development conditions. If, however, the runoff hydrographs had the configuration shown in Figure 2b, the volume of required storage would be less than the total volume difference.

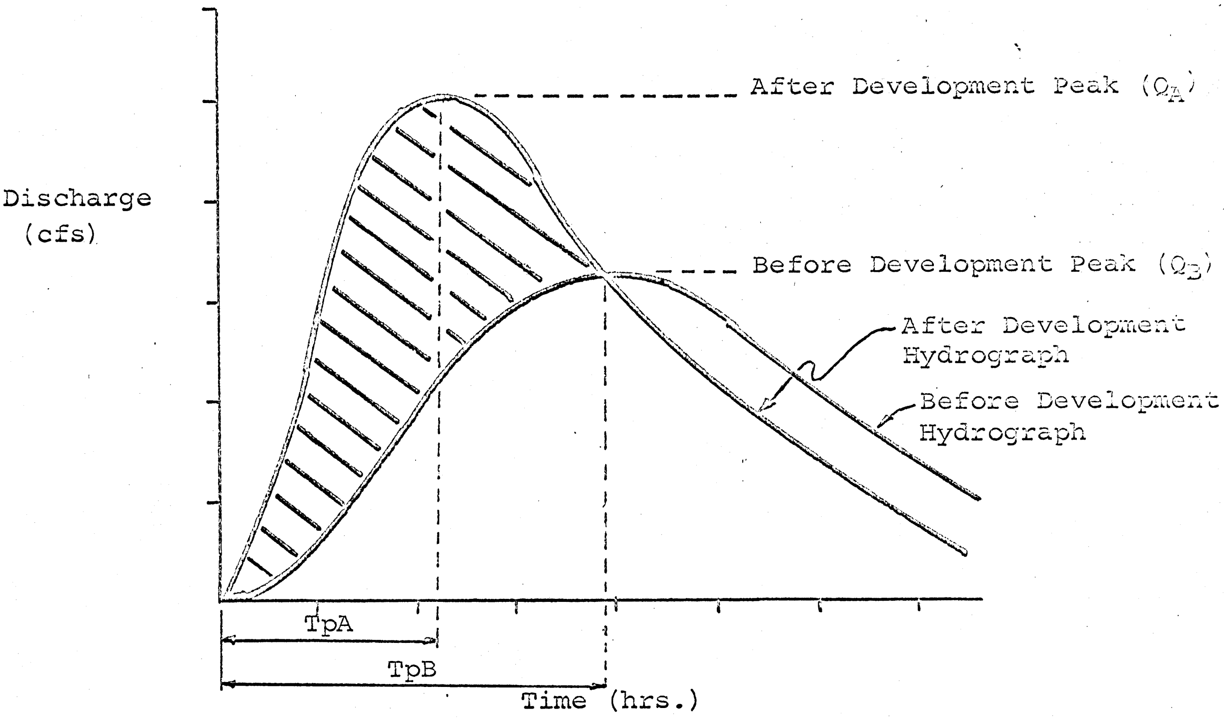

Figure 1 A

Comparison of Typical Before & After Development Runoff Hydrographs

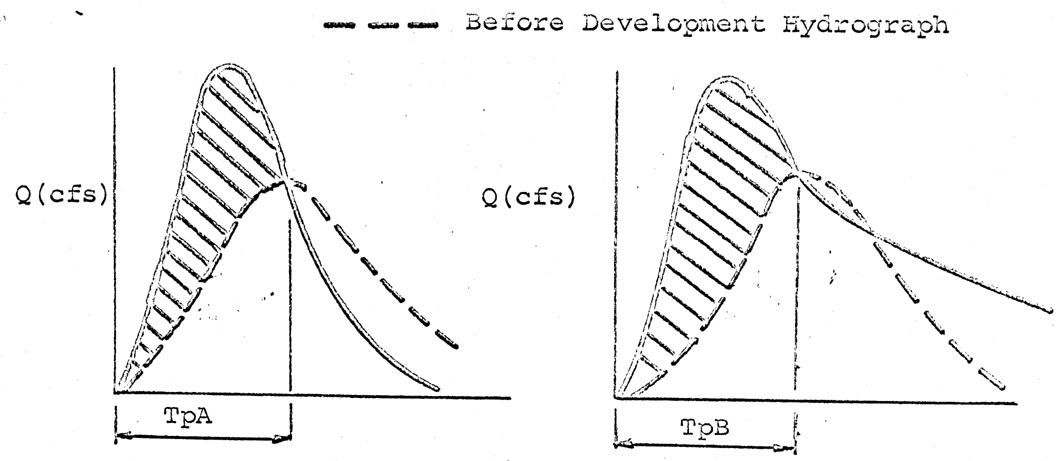

Fig 2a Fig 2b

Figure 2

Two possible relationships between Before-After Development Hydrographs

(Note: The before development Hydrograph and the outflow hydrograph are <u>not</u> assumed the same beyond TpB)

Trial routings have shown that for most of the possible pre and post development conditions volume of storage would be slightly less than the total difference in runoff volume. Therefore, for most areawide stormwater management planning, it seems that it would be adequate, if not somewhat conservative, to equate V_s with the total difference in runoff volume between pre and post development conditions. (In the case where it was anticipated that surface water ponds would provide a major portion of stormwater management, this assumption would be invalid and a modification factor would have to be applied. This will be discussed in a latter portion of this report.)

<u>Additional Assumptions</u>

The task now becomes one of evaluating the impact of all possible pre and post development conditions. This becomes further complicated by the fact that hydrologic soil conditions must also be assessed.

Therefore, further simplifying assumptions must be made in order to develop a workable procedure. These are as follows:

1) While soil conditions do effect runoff volume, they do not significantly affect the change in runoff volume brought about by changed land use. (The author realizes that this assumption has some shortcomings but it is valid within the constraints of the use of this tool).

2) All land use changes can be approximated within the following categories:

Existing Land Use	Future Land Use
Idle Land	Grassland
Woodland	Single Family Res.
Brushland	Garden Apts. & Townhouses
Grassland	60% Imp. (Commercial, Ind.)
Cropland	100% Impervious

Land undergoing construction will be a special category that will be dealt with on a limited basis.

Development of the Procedure

If one can accept the above assumptions, we can use the SCS hydrologic procedure to assign a Runoff Curve Number (RCN) to each of the land uses shown. Note: Hydrologic Soil Group B was used in curve number development.

TABLE 1

Land Use	RCN (for HSG"B")
Woodland	55
Idle Land	58
Brush	59
Grassland	61
Single Family Res.	70
Cropland	71
60% Impervious	83
Garden Apts.	85
Construction	89
100% Impervious	98

Using these curve numbers and varying rainfall amounts associated for storms from the 2-year frequency to 10-year frequency, the curves shown in Figure 3 were developed. These curves become the heart of the procedure. For a given rainfall amount, the impact of a land use change can be ascertained directly from the curves. Change in runoff is given in acre-feet/acre. A total volume increase is obtained by multiplying by the appropriate land area in acres.

Example:

Given: 10 Acre Tract -

Present land use: Woodland
Proposed land use: Commercial
60% Impervious

Using Fig. 3 Find the increase in runoff volume associated with a 4" rainfall

Solution:

Using a scale or set of dividers measure vertical distance up 4" rainfall line from curve for "woods" to curve for "60% impervious. Transfer distance to vertical scale with one end point on zero. Read runoff increase of 0.146 A.F./Ac. Multiply this result by 10Ac. to obtain solution of 14.6 A.F.1/ increase in runoff volume for the tract.

These curves are very flexible in that they can be used to ascertain volume increases for varying rainfall events. For instance, suppose storm water criteria dictates that the discharge from a future development for the 10-year storm must be reduced to that which now exists for a two-year storm. The volume increase would be obtained by measuring vertically from the intercept of the present land use curve and the appropriate 2-year rainfall to the intercept of the future land use curve and the appropriate 10-year rainfall.

1/ The units Acre Feet (A.F.) are used in computations to reduce size of numbers. 1 A.F. = 43,560 cubic feet.

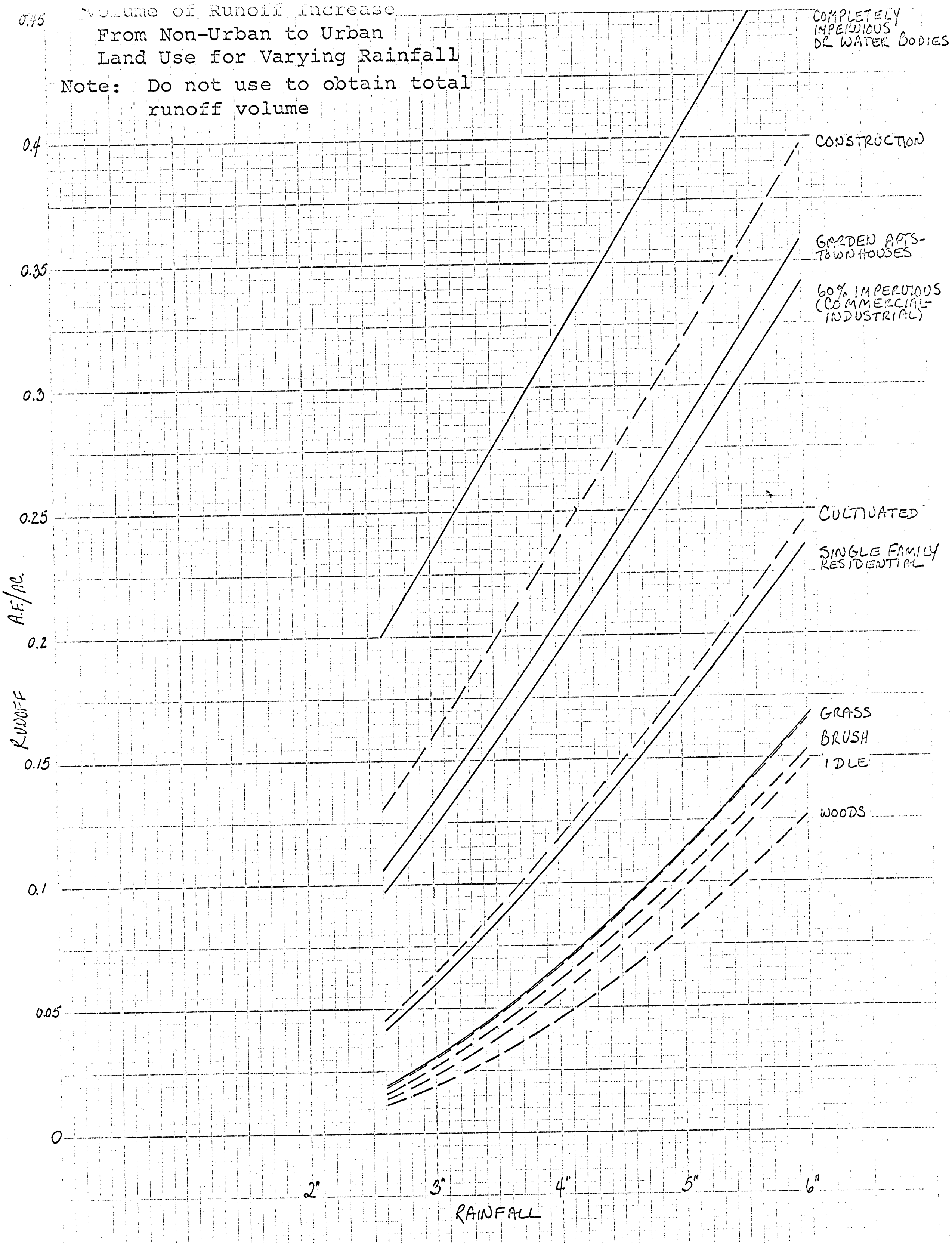
Volume of Runoff Increase
From Non-Urban to Urban
Land Use for Varying Rainfall
Note: Do not use to obtain total runoff volume
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
RUNOFF A.F./AC.
2"
3"
4"
5"
6"
RAINFALL
COMPLETELY IMPERVIOUS OR WATER BODIES
CONSTRUCTION
GARDEN APTS-TOWNHOUSES
60% IMPERVIOUS (COMMERCIAL-INDUSTRIAL)
CULTIVATED
SINGLE FAMILY RESIDENTIAL
GRASS
BRUSH
IDLE
WOODS

Figure 3

Modification for Local Application

If one is working in a small planning area such as a county, one can use the curves along with local storm water management criteria to develop a runoff increase matrix such as the one shown in Figure 4. The matrix shows all of the land use changes possible and the associated volume of runoff increase, again in AF/Ac, for a given stormwater management criteria. (In this case, control of the 2-yr.-24-hr. storm).

Example: Given - 20-Acre Tract

Location: Montgomery County, Maryland
Present land use: Cropland
Proposed land use: Garden Apartments

Using Fig. 3 - Find increase in runoff volume that would occur as a result of the 2-yr.-24-hr. rainfall.

Solution:

From Figure 3, observe the runoff increase factor for a Cropland → Garden Apartments. Conversion is .074 AF/Ac.

Multiplying this by 20Ac., we obtain the solution of 14.8 A.F. of increased runoff volume.

Multiple Land Use Conversions

So far, the discussion has been limited to conversion of one discrete land use to another. In areawide planning, this phenomena seldom, if ever, occurs. More often, a tract of land which may be developed is in 2 or more intermixed land uses. Furthermore, future development usually calls for 2 or more related but non-homogeneous land uses.

There are a number of ways that planners have of addressing this problem. Any technique that yields a systematic land area conversion from a present land use to future land use within the categories referred to earlier is acceptable for use in this procedure.

Grid Coding (A Digression)

The author would like to indulge in a slight digression to discuss a procedure for quantifying land use change that has been used with some success in Montgomery County Planning applications. That is the

RUNOFF INCREASE MATRIX
MONTGOMERY COUNTY, MARYLAND
2-YR.- 24-HOUR STORM
(Runoff Increase in Acre Feet/Acre)

Note: Numbers in Parenthesis Indicate Reduction in Volume

	Grassland	Single Family	60% Imp.	Garden Apts.	60% Imp.
Grassland	-	.032	.097	.110	.211
Cropland	(.036)	(.004)	.061	.074	.175
Woodland	.016	.048	.113	.126	.227
Brush	.006	.038	.103	.116	.217
Idle Land	.009	.041	.106	.119	.220
Construction 1/	-	.031	.096	.109	.210

1/ Use only if former land use is unknown

Figure 4

simple technique of grid coding.

Grid coding has a number of advantages in an areawide approach to stormwater management.

1) It allows for a systematic assessment of land use change;
2) It is simple to apply;
3) Grid size can be adjusted with the area to be studied; and
4) It is adaptable to both manual and electronic computer coding and evaluation.

The major disadvantages are:

1) The inaccuracies created by trying to approximate curvilinear data with a rectangular grid system; and
2) Inaccuracies due to human error for large tedious coding jobs.

These disadvantages can be minimized by making the grid size small enough to accurately reflect land use variations (As a rule of thumb, grid cell size should not exceed 1/50 of the overall planning area) and by adapting encoding procedure to an electronic computer or other electronic aid.

Briefly the coding procedure is as follows:

1) Rectangular grid cell overlay with uniform cells is fitted to map of existing land use and each cell is encoded with appropriate land use symbols (see Table 1); and
2) Identical grid cell overlay is fitted to a conceptual map of proposed future land use in exactly the same orientation as overlay in 1). Future land use is encoded using symbols in Table 2.

See Figure 5 for a graphical representation of encoding procedure.

The grid cell overlays can now be used by themselves to ascertain the total land use changes for the planning area.

Example: Given: Grid cell overlays in Figure 4
Grid cell size = 5 Ac

Find: Land use conversions in acres

Solution: From Figure 4 observe

Table 2

Land Use	Assigned Grid Code Number
Construction	1
Single Family Residential	2
Garden Apartments;Townhouses	3
100% Impervious; Water Bodies	4
60% Impervious; Commercial; Industrial	5
Grassland	6
Cropland	7
Woodland	8
Brush	9
Idle land	10

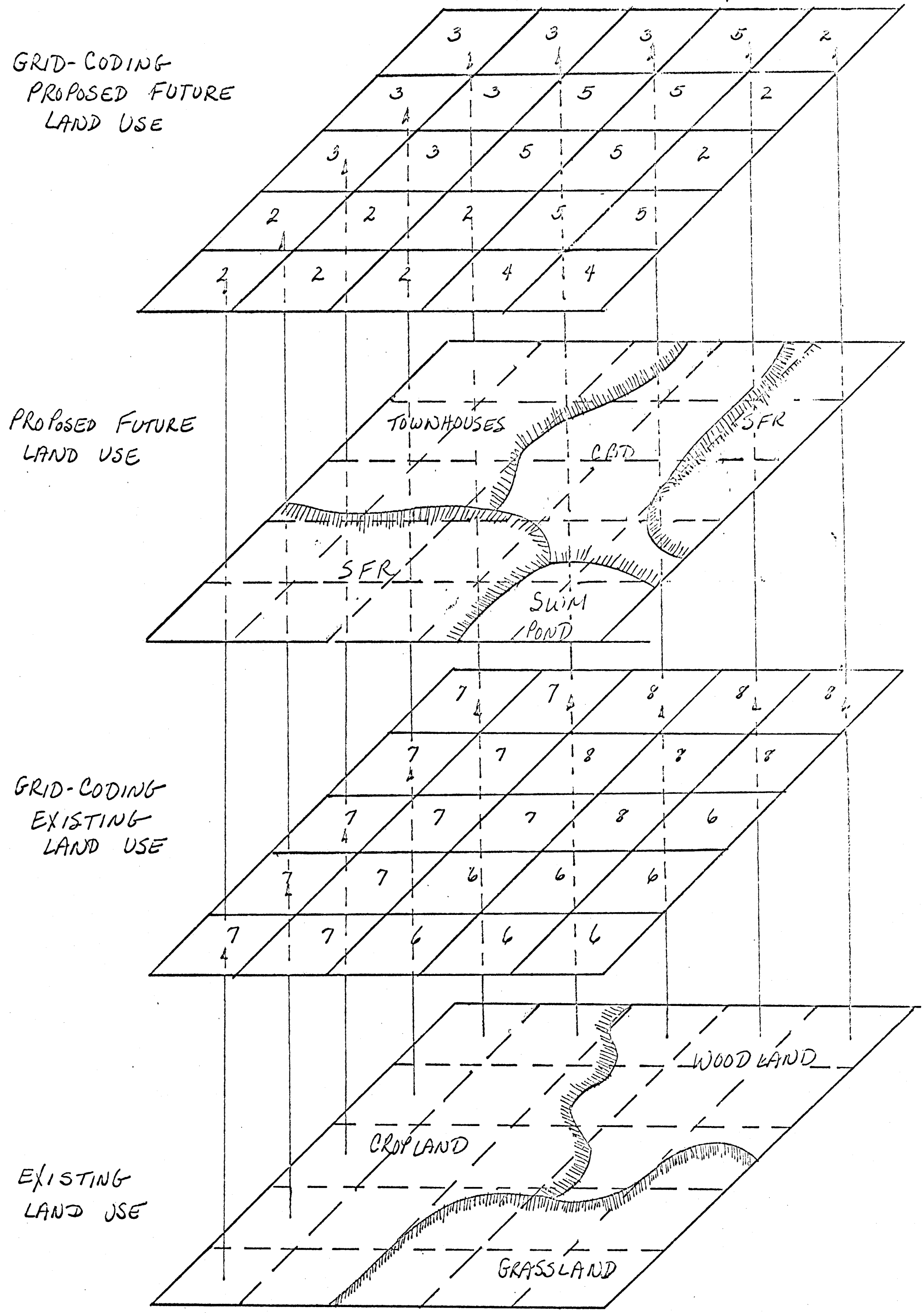

Figure 5

Graphical Representation
of
Grid Coding Procedure

Example Cont.

Conversion	Count	Total
7 → 2	////	4
7 → 3	//////	6
7 → 5	/	1
6 → 2	///	3
6 → 4	//	2
6 → 5	//	2
8 → 2	//	2
8 → 3	/	1
8 → 5	////	4
		25

Use Table 1 to convert codes to land use changes and multiply grid cells by 5Ac/cell to obtain final conversions.

Code	Land Use Conversion	Cell Count	Acres
7 → 2:	Cropland → SFR	4	20
7 → 3:	Cropland → Garden Apts.	6	30
7 → 5:	Cropland → 60% Imp.	1	5
6 → 2:	Grassland → SRF	3	15
6 → 4:	Grassland → Water	2	10
6 → 5:	Grassland → 60% Imp.	2	10
8 → 2:	Woodland → SFR	2	10
8 → 3:	Woodland → G.A.	1	5
8 → 5:	Woodland → 60% Imp.	4	20

It should be now easily recognized that the results of such a grid cell analysis can be used either in conjunction with Figure 3 or more simply with a matrix such as Figure 4 to yield to total volume of required stormwater management storage for a planning area.

Application of the Procedure

It is now possible to assess storm water management requirements for land that will be developed in the future and with some minor modifications and assumptions for land that has already been developed. For the first category, the procedure would be as follows:

1) Determine hydrologic sub-areas within the planning area;
2) Using an acceptable procedure summarize land use change within a sub-area;

3) For each conversion category, multiply appropriate acreage by runoff increase factor from Figure 3 or facsimile of Figure 4 applicable in your area.

4) Sum result to get increased runoff volume for entire sub-area.

For the second category, steps 1,2 and 4 would be the same. For item 3) some judgment would have to be used in obtaining runoff factors. If former land use is known, one could work backwards on Figure 3 or 4. More than likely, however, this will not be the case. Therefore, some average runoff reduction factors will have to be arrived at using existing stormwater management policy and engineering judgment.

<u>Use of the Procedure</u>

The procedure can be used in conjunction with other stormwater management tools to affect an areawide stormwater management plan. It could be used in conjunction with topographic and soils information to determine potential locations for stormwater management facilities. It could be used in conjunction with studies relating stormwater management cost to volume of storage requirements (eg: Storm Water Management Cost Study - Thomas & DeTullio, 1977) in order to ascertain stormwater management costs on an areawide basis. It could be used to compare the cost and effectiveness of various competing stormwater management schemes.

<u>Special Consideration for Ponds</u>

It was stated earlier that the basic underlying assumption of the procedure was that the volume of storage required to affect stormwater management was equal to the difference in runoff volume between present and future land use for a given rainfall event. It can be shown that in most cases this is conservative, that is, actual volume required will be less due to flood routing. However, when surface water ponds are constructed, design criteria dictates such facilities must "control" a storm in excess of the 2-year storm, usually the 10-year storm. Such "control" is usually accomplished using a multi-stage spillway system which provides stormwater management control up to the two-year storm and rapid spillway release of anything in excess of the two-year storm. This arrangement implies some additional storage for the facility above that which is required for stormwater management. As a rule of thumb, therefore, to be used when ponds provide a major portion of stormwater management, the author would suggest that

the volume of runoff increase, obtained by methods outlined in this report, be multiplied by 1.5 in order to obtain V_s. Please note that this factor is somewhat arbitrary and should be used with caution.

Additional refinement of the relationship between stormwater management storage requirements and total storage requirements remains for some future study.

Restrictions In Use

As stated earlier, the procedure is designed to be used as a planning rather than a design tool. It is based on some simplifying assumptions which make it imperative that it is not used beyond the bounds for which it is intended. These restrictions are as follows:

1) Procedure should not be used for planning areas under 100 acres or for individual sub-basins over 2000 acres. For areas less than 100 acres, small errors in land use change conversion can be significant. For areas over 2000 acres, drainage systems are too complex; therefore, more vigorous models should be used;

2) Figure 3 may not be used to obtain total runoff. The assumptions upon which it is based are only valid in computing differences in runoff;

3) Figure 3 should not be extrapolated;

4) Figure 4 is valid only in Montgomery County, Maryland;

5) No attempt should be made to use the procedure to develop peak rates of discharge or flood hydrographs. It is to be used to compute runoff volume increases only;

6) Results are to be used for planning purposes only. Final design must be based on more vigorous hydrologic procedures, such as those outlined in SCS Technical Release 55.

Conclusion

Planners faced with the task of ascertaining impacts of land use changes on basin hydrology and the need for stormwater

management need a procedure for rapid analysis. The preceding material can be used to fill this void if it is used with the necessary precautions. The procedure is based primarily on the Runoff Curve Number Procedure of the U.S. Soil Conservation Service which has been used with great success for many years on small watersheds throughout the U.S. and the world. The underlying assumptions which are used to simplify the procedure are not detrimental if used in the proper context. This paper is intended to present only a skeletal outline of a flexible procedure. It remains only for the user to apply his own judgment and ingenuity in making minor adaptations to the model to fit his individual planning needs.

REFERENCES

1. USDA SCS TR 55
2. USDA SCS Eng. Field Manual Ch. 2
3. USDA SCS NEH Chapter 4
4. USDA SCS TR 16
5. MSCD On=Site Storm Water Management Policy
6. DeTullio-Thomas - Storm Water Management Cost Study
7. I.P.A. Staff - Land Use Study for Seneca Creek Watershed

SHAFFNER'S PAPER COMMENTS 10/27/77 RRB

1. OUTFLOW HYDROGRAPH FOR A SWM SYSTEM IS NOT NECESSARILY THE SAME AS THE INFLOW HYDROGRAPH FOR PRE-DEVELOPED CONDITIONS ∴ STORAGE VOLUMES SHOWN IN THE REPORT ARE FAIRLY CONSERVATIVE.

I AM SURE THE AUTHOR WAS AWARE OF THIS.

2. COULD BE INCORPORATED AS A FAIRLY GOOD PLANNING TOOL (IF IS USED AS ONLY THAT AND NOT FOR DETAILED DESIGN).

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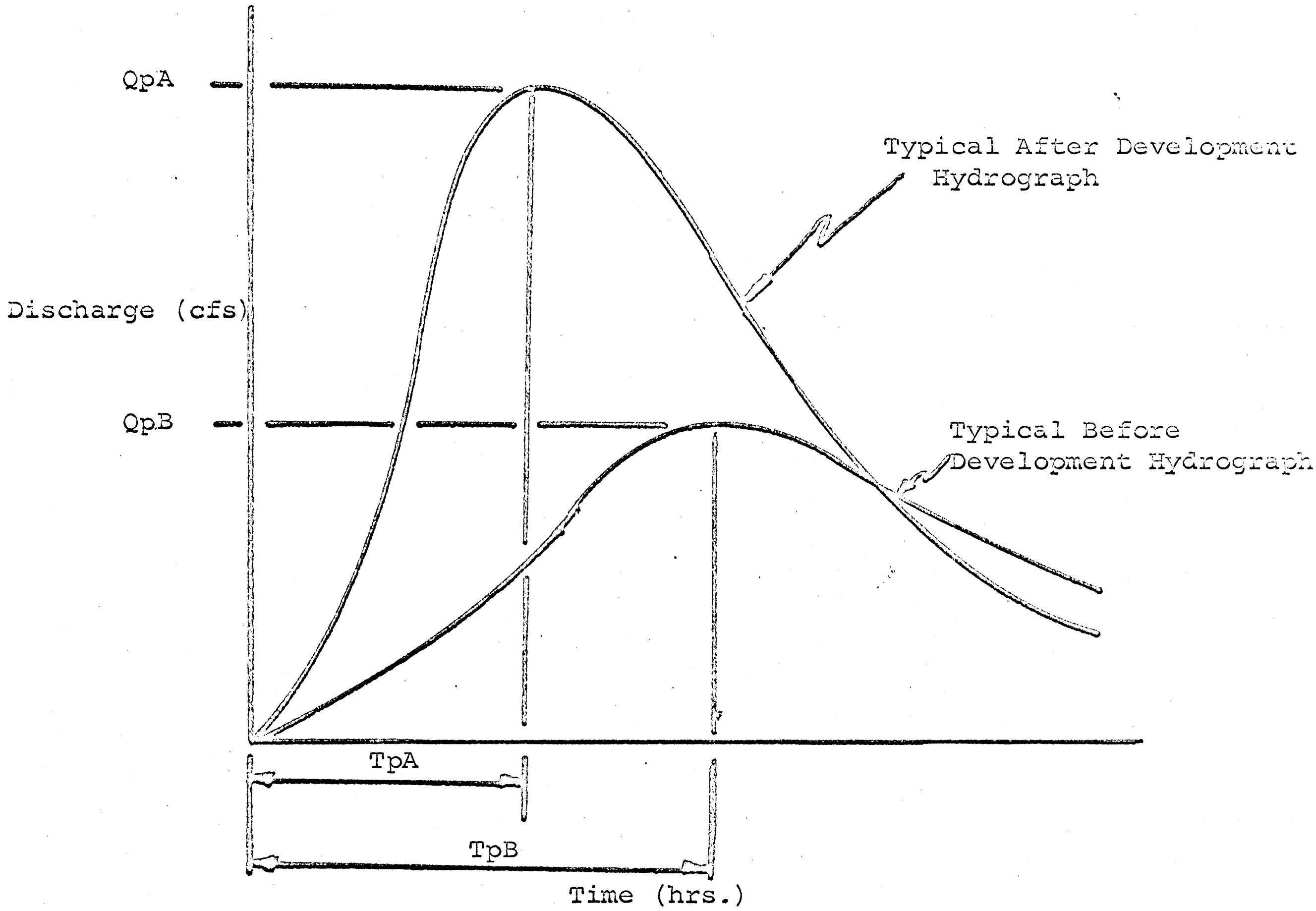

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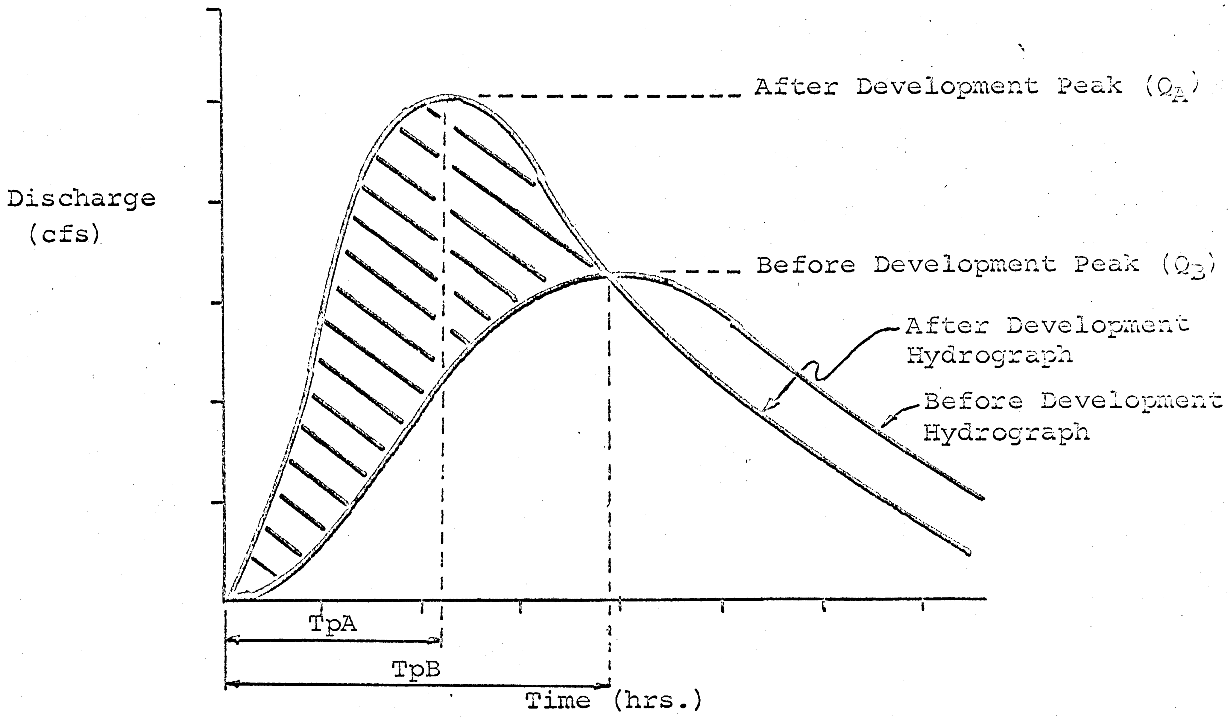

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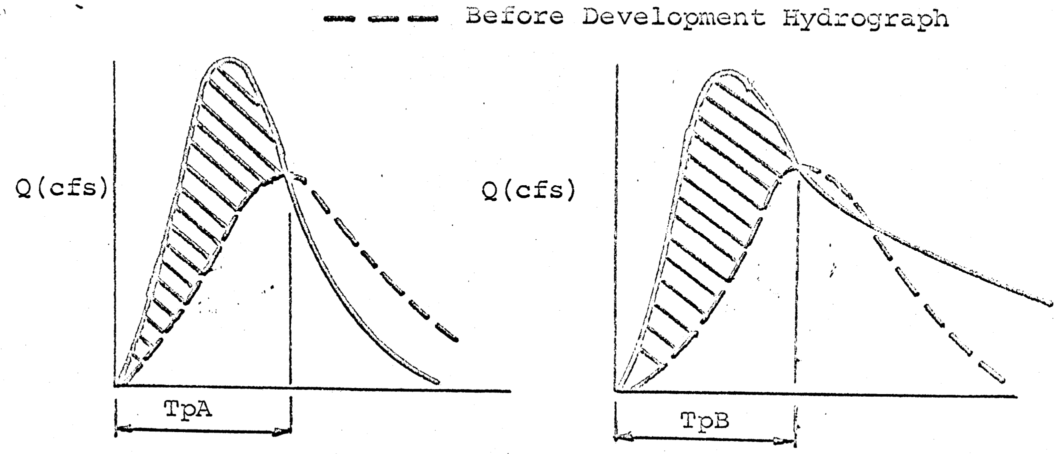

Fig 2a Fig 2b

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Solution:

Using a scale or set of dividers measure vertical distance up 4" rainfall line from curve for "woods" to curve for "60% impervious. Transfer distance to vertical scale with one end point on zero. Read runoff increase of 0.146 A.F./Ac. Multiply this result by 10Ac. to obtain solution of 14.6 A.F.1/ increase in runoff volume for the tract.

These curves are very flexible in that they can be used to ascertain volume increases for varying rainfall events. For instance, suppose storm water criteria dictates that the discharge from a future development for the 10-year storm must be reduced to that which now exists for a two-year storm. The volume increase would be obtained by measuring vertically from the intercept of the present land use curve and the appropriate 2-year rainfall to the intercept of the future land use curve and the appropriate 10-year rainfall.

1/ The units Acre Feet (A.F.) are used in computations to reduce size of numbers. 1 A.F. = 43,560 cubic feet.

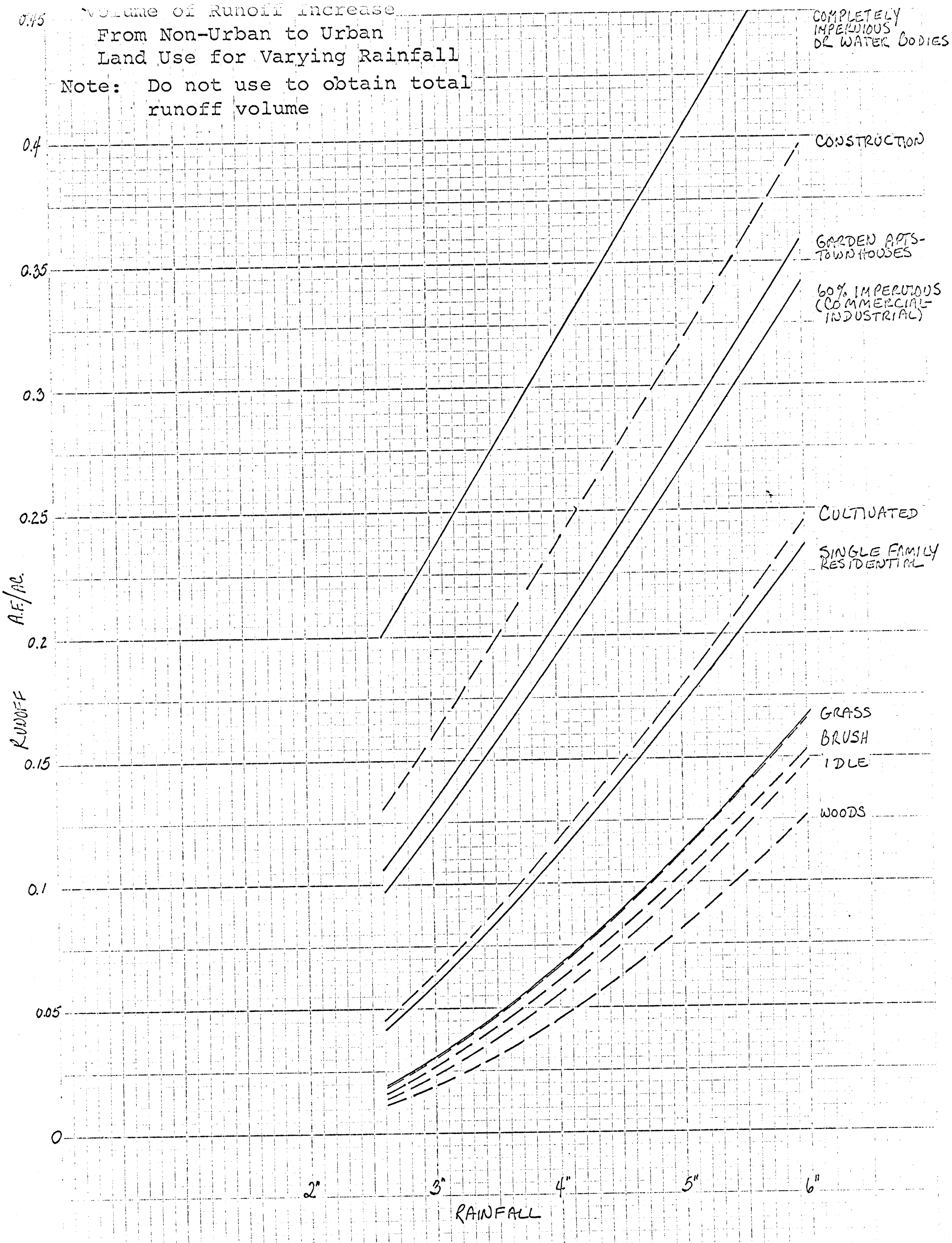

Volume of Runoff Increase
From Non-Urban to Urban
Land Use for Varying Rainfall
Note: Do not use to obtain total runoff volume
COMPLETELY IMPERVIOUS OR WATER BODIES
CONSTRUCTION
GARDEN APTS-TOWNHOUSES
60% IMPERVIOUS (COMMERCIAL-INDUSTRIAL)
CULTIVATED
SINGLE FAMILY RESIDENTIAL
GRASS
BRUSH
IDLE
WOODS
RUNOFF A.F./AC.
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2"
3"
4"
5"
6"
RAINFALL

Figure 3

Modification for Local Application

If one is working in a small planning area such as a county, one can use the curves along with local storm water management criteria to develop a runoff increase matrix such as the one shown in Figure 4. The matrix shows all of the land use changes possible and the associated volume of runoff increase, again in AF/Ac, for a given stormwater management criteria. (In this case, control of the 2-yr.-24-hr. storm).

Example: Given - 20-Acre Tract

Location: Montgomery County, Maryland
Present land use: Cropland
Proposed land use: Garden Apartments

Using Fig. 3 - Find increase in runoff volume that would occur as a result of the 2-yr.-24-hr. rainfall.

Solution:

From Figure 3, observe the runoff increase factor for a Cropland → Garden Apartments. Conversion is .074 AF/Ac.

Multiplying this by 20Ac., we obtain the solution of 14.8 A.F. of increased runoff volume.

Multiple Land Use Conversions

So far, the discussion has been limited to conversion of one discrete land use to another. In areawide planning, this phenomena seldom, if ever, occurs. More often, a tract of land which may be developed is in 2 or more intermixed land uses. Furthermore, future development usually calls for 2 or more related but non-homogeneous land uses.

There are a number of ways that planners have of addressing this problem. Any technique that yields a systematic land area conversion from a present land use to future land use within the categories referred to earlier is acceptable for use in this procedure.

Grid Coding (A Digression)

The author would like to indulge in a slight digression to discuss a procedure for quantifying land use change that has been used with some success in Montgomery County Planning applications. That is the

RUNOFF INCREASE MATRIX
MONTGOMERY COUNTY, MARYLAND
2-YR.- 24-HOUR STORM
(Runoff Increase in Acre Feet/Acre)

Note: Numbers in Parenthesis Indicate Reduction in Volume

	Grassland	Single Family	60% Imp.	Garden Apts.	60% Imp.
Grassland	-	.032	.097	.110	.211
Cropland	(.036)	(.004)	.061	.074	.175
Woodland	.016	.048	.113	.126	.227
Brush	.006	.038	.103	.116	.217
Idle Land	.009	.041	.106	.119	.220
Construction [1/]	-	.031	.096	.109	.210

1/ Use only if former land use is unknown

Figure 4

simple technique of grid coding.

Grid coding has a number of advantages in an areawide approach to stormwater management.

1) It allows for a systematic assessment of land use change;
2) It is simple to apply;
3) Grid size can be adjusted with the area to be studied; and
4) It is adaptable to both manual and electronic computer coding and evaluation.

The major disadvantages are:

1) The inaccuracies created by trying to approximate curvilinear data with a rectangular grid system; and
2) Inaccuracies due to human error for large tedious coding jobs.

These disadvantages can be minimized by making the grid size small enough to accurately reflect land use variations (As a rule of thumb, grid cell size should not exceed 1/50 of the overall planning area) and by adapting encoding procedure to an electronic computer or other electronic aid.

Briefly the coding procedure is as follows:

1) Rectangular grid cell overlay with uniform cells is fitted to map of existing land use and each cell is encoded with appropriate land use symbols (see Table 1); and
2) Identical grid cell overlay is fitted to a conceptual map of proposed future land use in exactly the same orientation as overlay in 1). Future land use is encoded using symbols in Table 2.

See Figure 5 for a graphical representation of encoding procedure.

The grid cell overlays can now be used by themselves to ascertain the total land use changes for the planning area.

Example:	Given:	Grid cell overlays in Figure 4 Grid cell size = 5 Ac
	Find:	Land use conversions in acres
Solution:	From Figure 4 observe	

Table 2

Land Use	Assigned Grid Code Number
Construction	1
Single Family Residential	2
Garden Apartments;Townhouses	3
100% Impervious; Water Bodies	4
60% Impervious; Commercial; Industrial	5
Grassland	6
Cropland	7
Woodland	8
Brush	9
Idle land	10

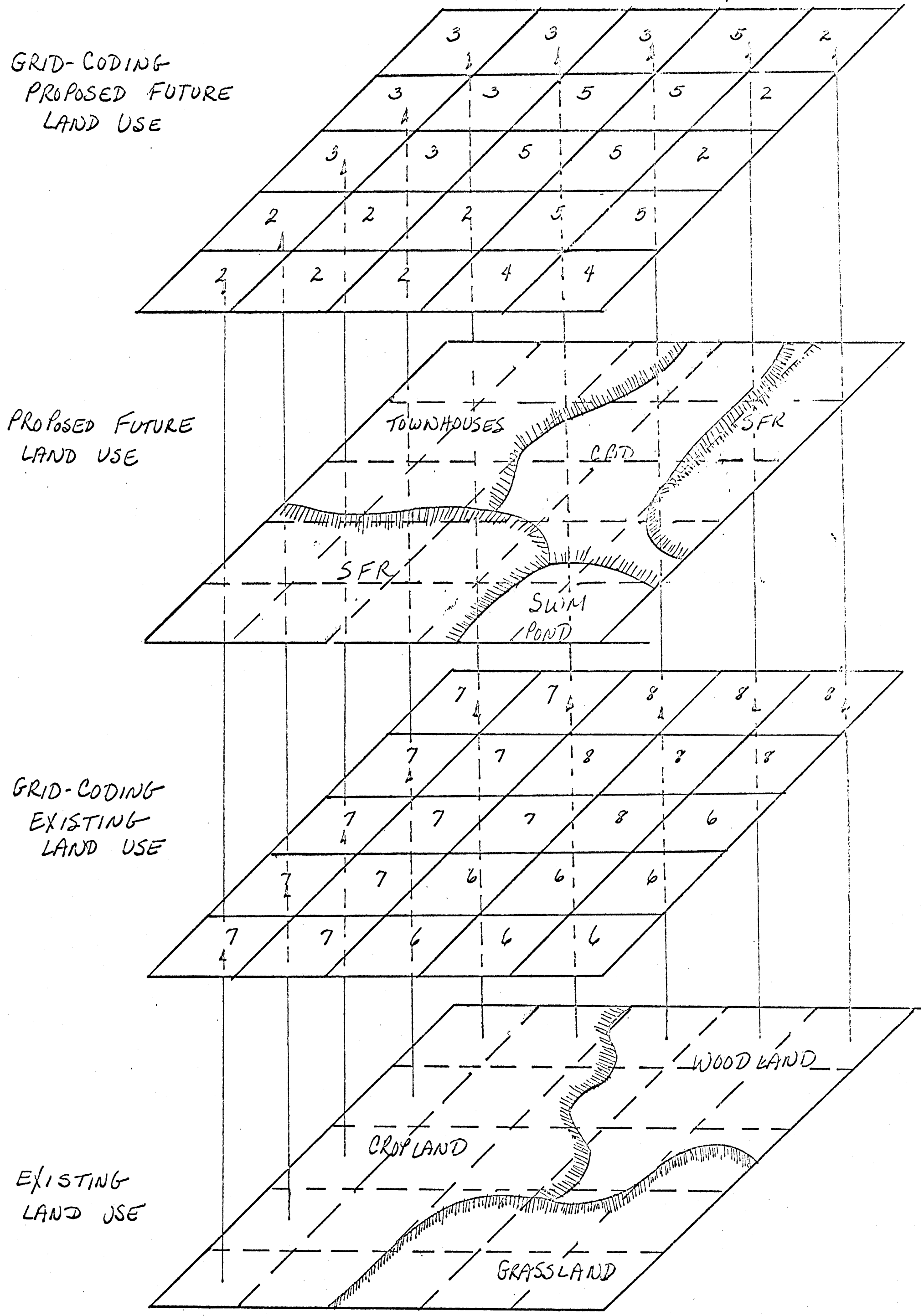


Figure 5

Graphical Representation
of
Grid Coding Procedure

Example Cont.

Conversion	Count	Total
7 → 2	////	4
7 → 3	//////	6
7 → 5	/	1
6 → 2	///	3
6 → 4	//	2
6 → 5	//	2
8 → 2	//	2
8 → 3	/	1
8 → 5	////	4
		25

Use Table 1 to convert codes to land use changes and multiply grid cells by 5Ac/cell to obtain final conversions.

Code	Land Use Conversion	Cell Count	Acres
7 → 2:	Cropland → SFR	4	20
7 → 3:	Cropland → Garden Apts.	6	30
7 → 5:	Cropland → 60% Imp.	1	5
6 → 2:	Grassland → SRF	3	15
6 → 4:	Grassland → Water	2	10
6 → 5:	Grassland → 60% Imp.	2	10
8 → 2:	Woodland → SFR	2	10
8 → 3:	Woodland → G.A.	1	5
8 → 5:	Woodland → 60% Imp.	4	20

It should be now easily recognized that the results of such a grid cell analysis can be used either in conjunction with Figure 3 or more simply with a matrix such as Figure 4 to yield to total volume of required stormwater management storage for a planning area.

Application of the Procedure

It is now possible to assess storm water management requirements for land that will be developed in the future and with some minor modifications and assumptions for land that has already been developed. For the first category, the procedure would be as follows:

1) Determine hydrologic sub-areas within the planning area;
2) Using an acceptable procedure summarize land use change within a sub-area;

3) For each conversion category, multiply appropriate acreage by runoff increase factor from Figure 3 or facsimile of Figure 4 applicable in your area.

4) Sum result to get increased runoff volume for entire sub-area.

For the second category, steps 1,2 and 4 would be the same. For item 3) some judgment would have to be used in obtaining runoff factors. If former land use is known, one could work backwards on Figure 3 or 4. More than likely, however, this will not be the case. Therefore, some average runoff reduction factors will have to be arrived at using existing stormwater management policy and engineering judgment.

<u>Use of the Procedure</u>

The procedure can be used in conjunction with other stormwater management tools to affect an areawide stormwater management plan. It could be used in conjunction with topographic and soils information to determine potential locations for stormwater management facilities. It could be used in conjunction with studies relating stormwater management cost to volume of storage requirements (eg: Storm Water Management Cost Study - Thomas & DeTullio, 1977) in order to ascertain stormwater management costs on an areawide basis. It could be used to compare the cost and effectiveness of various competing stormwater management schemes.

<u>Special Consideration for Ponds</u>

It was stated earlier that the basic underlying assumption of the procedure was that the volume of storage required to affect stormwater management was equal to the difference in runoff volume between present and future land use for a given rainfall event. It can be shown that in most cases this is conservative, that is, actual volume required will be less due to flood routing. However, when surface water ponds are constructed, design criteria dictates such facilities must "control" a storm in excess of the 2-year storm, usually the 10-year storm. Such "control" is usually accomplished using a multi-stage spillway system which provides stormwater management control up to the two-year storm and rapid spillway release of anything in excess of the two-year storm. This arrangement implies some additional storage for the facility above that which is required for stormwater management. As a rule of thumb, therefore, to be used when ponds provide a major portion of stormwater management, the author would suggest that

the volume of runoff increase, obtained by methods outlined in this report, be multiplied by 1.5 in order to obtain V_s. Please note that this factor is somewhat arbitrary and should be used with caution.

Additional refinement of the relationship between stormwater management storage requirements and total storage requirements remains for some future study.

Restrictions In Use

As stated earlier, the procedure is designed to be used as a planning rather than a design tool. It is based on some simplifying assumptions which make it imperative that it is not used beyond the bounds for which it is intended. These restrictions are as follows:

1) Procedure should not be used for planning areas under 100 acres or for individual sub-basins over 2000 acres. For areas less than 100 acres, small errors in land use change conversion can be significant. For areas over 2000 acres, drainage systems are too complex; therefore, more vigorous models should be used;

2) Figure 3 may not be used to obtain total runoff. The assumptions upon which it is based are only valid in computing differences in runoff;

3) Figure 3 should not be extrapolated;

4) Figure 4 is valid only in Montgomery County, Maryland;

5) No attempt should be made to use the procedure to develop peak rates of discharge or flood hydrographs. It is to be used to compute runoff volume increases only;

6) Results are to be used for planning purposes only. Final design must be based on more vigorous hydrologic procedures, such as those outlined in SCS Technical Release 55.

Conclusion

Planners faced with the task of ascertaining impacts of land use changes on basin hydrology and the need for stormwater

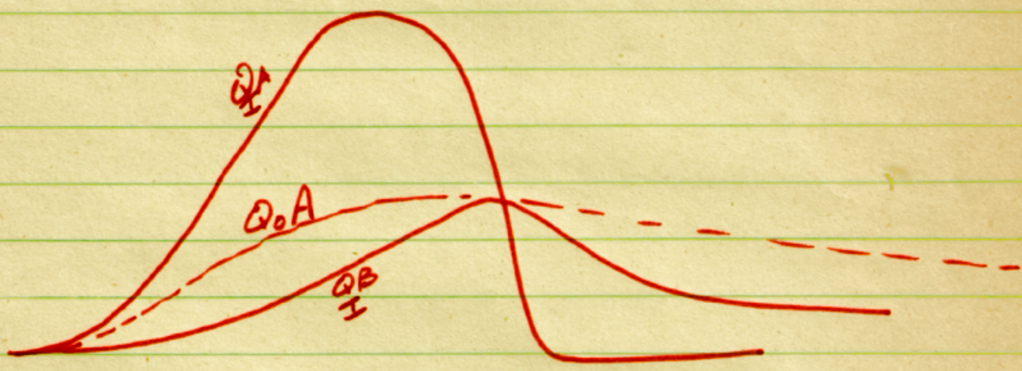
management need a procedure for rapid analysis. The preceding material can be used to fill this void if it is used with the necessary precautions. The procedure is based primarily on the Runoff Curve Number Procedure of the U.S. Soil Conservation Service which has been used with great success for many years on small watersheds throughout the U.S. and the world. The underlying assumptions which are used to simplify the procedure are not detrimental if used in the proper context. This paper is intended to present only a skeletal outline of a flexible procedure. It remains only for the user to apply his own judgment and ingenuity in making minor adaptations to the model to fit his individual planning needs.

REFERENCES

1. USDA SCS TR 55
2. USDA SCS Eng. Field Manual Ch. 2
3. USDA SCS NEH Chapter 4
4. USDA SCS TR 16
5. MSCD On=Site Storm Water Management Policy
6. DeTullio-Thomas - Storm Water Management Cost Study
7. I.P.A. Staff - Land Use Study for Seneca Creek Watershed

SHAFFNER'S PAPER COMMENTS 10/27/77 RRB

1. OUTFLOW HYDROGRAPH FOR A SWM SYSTEM IS NOT NECESSARILY THE SAME AS THE INFLOW HYDROGRAPH FOR PRE-DEVELOPED CONDITIONS ∴ STORAGE VOLUMES SHOWN IN THE REPORT ARE FAIRLY CONSERVATIVE.



I AM SURE THE AUTHOR WAS AWARE OF THIS.

2. COULD BE INCORPORATED AS A FAIRLY GOOD PLANNING TOOL (IF IS USED AS ONLY THAT AND NOT FOR DETAILED DESIGN).